Fiscal Policy Interventions at the Zero Lower Bound[☆]

Sabri Boubaker[a,b], Duc Khuong Nguyen[c,d], Nikos Paltalidis[e,*]

[a] South Champagne Business School, Troyes, France
[b] IRG, Université Paris Est, Paris, France
[c] IPAG Business School, Paris, France
[d] School of Public and Environment Affairs, Indiana University, Bloomington, United States
[e] Durham University Business School, Durham University

Abstract

We build on a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model to explore the macroeconomic consequences of fiscal expansionary shocks during the economic crisis of 2008 in the eurozone. In this setting, we find that the big four eurozone economies (France, Germany, Italy, and Spain) can effectively escape from their liquidity trap through fiscal policy interventions caused by government purchases. We estimate the government spending multiplier to be above 1.8 when this policy is associated with a long-term commitment to keeping the nominal interest rate at the zero lower bound, as suggested by Krugman (1998). Notably, the short-term deficit effect on the budget balance can be offset five years after the implementation of a large spending program. We also show that alternative policies with tax cuts that expand the supply do not appear to have the same power in the short run. Moreover, we provide novel empirical evidence that a large government debt renders a government spending policy ineffective.

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[*] *Corresponding Author*: Department of Economics and Finance, Durham University Business School, Durham University, Mill Hill Lane, Durham, DH1 3LB, United Kingdom. Phone: +44 191 334 0113; fax: +44 191 334 5201; email addresses: S. Boubaker (sabri.boubaker@get-mail.fr), D.K. Nguyen (duc.nguyen@ipag.fr), N. Paltalidis (nikos.e.paltalidis@durham.ac.uk).

1. Introduction

> It would be extremely helpful if central banks could count on other policymakers, particularly fiscal policymakers, to take on some of the burden of stabilizing the economy during the next recession.
>
> (Ben S. Bernanke[1])

The financial crisis of 2008 led to a global recession and to an intense debate about the limitations of monetary policy and the effectiveness of fiscal stimuli. After years of massive stimulus policies with nominal interest rates at the zero lower bound from the major central banks in the United States, Europe, and Japan, inflation remains stubbornly low and the global economies have not recovered as much as expected. As stated by the former Federal Reserve Chair Ben Bernanke at the Brookings Institute, and as highlighted a few weeks later by the European Central Bank (ECB) Chair Mario Draghi, central banks are close to the limits of what their stimulus policies (widely known as quantitative easing) can achieve; therefore, fiscal policymakers have to take action and complement these policies.[2] Notably, Japan recently applied large fiscal expansions but failed to stimulate the demand and to escape from its liquidity trap.

Consequently, the effectiveness of the expansionary fiscal policy has been challenged and questioned. What is the effect of a government spending shock? How does the output respond to a tax cut when the interest rates are at the zero lower bound? How does the fiscal multiplier change when the zero bound is not binding? The answers from the existing literature are not conclusive. While some authors, such as Cogan et al. (2010), find a multiplier below unity from a New Keynesian model, others, such as Ramey (2011a), predict the multiplier to be above 1.0, depending on the timing. Additionally, Christiano et al. (2011) document

[1] Article in the Brookings Institute blog, September 13, 2016, entitled "Modifying the Fed's policy framework: Does a higher inflation target beat negative interest rates?"
https://www.brookings.edu/blog/ben-bernanke/2016/09/13/modifying-the-feds-policy-framework-does-a-higher-inflation-target-beat-negative-interest-rates/

[2] Remarks in the European Parliament, Brussels, September 25, 2016.
https://www.ecb.europa.eu/press/key/date/2016/html/sp160926_2.en.html

that the government spending multiplier is above 1.0 when the central bank commits to constant interest rates over the long run and below 1.0 otherwise.

The debate is especially intense in Europe, where, quite recently, though without success since growth remains anemic, the ECB ramped up its stimulus program repeatedly by cutting deposit interest rates even below zero and accelerating its monthly bond purchase program.[3] Should eurozone economies have adopted a more aggressive unconventional fiscal policy to boost growth? How do tax cuts and government spending affect their economic growth under the actual economic circumstances? In this paper, we address these critical issues by examining the effectiveness of a government spending shock and an income tax cut at the zero lower bound to provide novel empirical evidence for the four largest eurozone economies, namely Germany, France, Italy, and Spain. We also compare the findings obtained with those of a positive nominal interest rate policy to determine how the fiscal multiplier changes in a distinctively different interest rate setting.

We build our theoretical framework on a New Keynesian dynamic stochastic general equilibrium (DSGE) model developed by Eggertsson (2010) and extended by Denes et al. (2013), in which they examine the effects of government purchase shocks and tax cuts on the stimulation of an economy when the zero lower bound is binding. In the model, the economy is subject to government spending and tax cut shocks, while the nominal interest rate is allowed to remain at the zero lower bound and does not respond to changes in the fiscal policy. The long-term commitment to generating inflation by keeping the nominal interest rate constant at the zero lower bound is similar in spirit to Christiano et al. (2011). Accordingly, the model allows us to use a strict Taylor rule policy. Under this rule the expansionary policy shock creates inflation and leads to higher interest rates. when the nominal interest rate rises in response to an expansionary policy shock, which creates inflation. Another key assumption

[3] See Joyce et al. (2012) for an analysis of the European Central Bank (ECB) quantitative easing program, Eser and Schwaab (2016) for a detailed discussion on the securities market program employed by the ECB, and Boubaker et al. (2017) on the role of unconventional monetary policies in risk and asset allocation decisions.

is that lump sum taxes are used to budget the government balance and to finance government spending. Our work modifies some of the theoretical assumptions of Eggertsson (2010) and Denes et al. (2013), such as tax cuts and the inflation rate at the zero lower bound, and focuses on the short- and medium-run effects of these policies on the stimulation of growth. Notably, only two previous empirical papers estimate fiscal multipliers at the zero lower bound (Ramey, 2011a for the United States; Crafts and Mills, 2013 for the United Kingdom), and only one compares the differences between the zero lower bound and the positive nominal interest rate policies in the United States (Ramey and Zubairy, 2018).[4] In addition, our paper contributes to the standard fiscal multiplier literature by showing that the government spending multiplier is larger than 1.0 and that tax cuts fail to stimulate growth effectively in the big four eurozone economies. Most estimates of the multiplier in previous studies are between 0.5 and 0.8 (e.g., Cogan et al., 2010; Beetsma and Giuliodori, 2011).

At the calibration stage, we empirically map the New Keynesian DSGE model into a state-space model that allows for a structural vector autoregressive (SVAR) analysis with macroeconomic variables and exogenous shocks. This approach is similar in spirit to the methods proposed by Blanchard and Perotti (2002) and Beetsma and Giuliodori (2011). We particularly examine the effects of government spending and tax cuts in three scenarios: (i) the interest rate is at the zero lower bound but following the change in fiscal policy in that the nominal interest rate rises and the zero lower bound does not bind; (ii) the interest rate is at the zero lower bound and does not respond to the fiscal policy shocks, and hence the zero bound is binding from the short to the medium term; (iii) there is a government budget constraint that does not allow the government balance to exceed the 3.0% deficit due to a large government debt in the first year of government fiscal intervention.

[4] In a related study, Leeper et al. (2010) use a neoclassical growth model to identify the effectiveness of an expansionary fiscal policy when it dynamically adjusts to the level of economic activity and to changes in the level of government debt. However, their work does not consider the interactions between fiscal policy and monetary policy, particularly when the nominal interest rate is near or at the zero lower bound.

We show that a positive shock to government spending (investment and consumption) can stimulate the eurozone economies effectively. In particular, when the nominal interest rate is at the zero lower bound and does not respond to government spending shocks and to an increase in inflation, the government spending multiplier becomes almost twice as large, since it is estimated to be higher than 1.8 for all four eurozone economies. In this scenario, the central bank focuses purely on stimulating the output, future inflation is allowed to increase, and the zero lower bound is binding from the short to the medium term, resembling the paradox of thrift as analyzed by Keynes (1936). As a result, the short-run effects on the output with a zero interest rate policy are substantially affected by the long-run expectation that the nominal interest rates will stay at the zero lower bound. Krugman (1998) suggests that policy commitments to keeping the interest rate at zero for a longer period, compared with the no-commitment policy, is an effective way to stimulate an economy. Eggertsson and Woodford (2003, 2004) argue that an economy can escape from the liquidity trap at the zero bound with a commitment to future high inflation. More precisely, the implementation of a government spending program can stabilize an economy in a time-consistent way (a maximum of three years from the implementation) with a positive long-run effect on the tax revenues. Importantly, the short-term effect on the budget balance can be offset and improved five years after the implementation of this policy. On the contrary, in the same nominal interest rate scenario, tax cuts are estimated to have an effect on the output that is much smaller than 1.0. A similar scenario is simulated by Christiano et al. (2011) for the US economy, and the government spending multiplier is estimated to be much larger than 1.0.

We also simulate a scenario in which, following government spending shocks and inflationary pressures, the nominal interest rates increase and the zero lower bound is not binding. In this case, the government spending multiplier is much lower, between 1.0 and 1.1. Moreover, the effect of tax cuts on the output is very low, from 0.1 to 0.2. Therefore, tax cuts when the zero lower bound is not binding are not an effective method of stimulating the big

four eurozone economies. Moreover, we find that a large government debt significantly affects the size of both government spending and tax multipliers, rendering these policies ineffective.

Overall, our findings suggest that an unconventional fiscal policy with an increase in government purchases along with a zero lower bound policy is effective in stimulating growth in the big four eurozone economies as well in counteracting a recession and deflationary pressures. Moreover, our results are in line with the works of Cogan et al. (2010) and Christiano et al. (2011), which show that government spending multipliers should be large and effective to stimulate an economy at the zero lower bound. Eggertsson (2010) and Denes et al. (2013) take one step further by analyzing both the effects of government spending shocks and many different tax cuts at the zero lower bound.

The remainder of this paper is organized as follows. Section 2 describes the literature review. Section 3 presents the methodological approach. Section 4 depicts the data set and analyzes the results. Section 5 concludes.

2. Literature review

The issue of the zero bound nominal interest rate constraint when expansionary monetary policy fails to stimulate the aggregate demand was first developed as a theoretical possibility by Keynes (1936) and gave rise to a macroeconomic phenomenon commonly known as a "liquidity trap." For decades, the question regarding the appropriate policy at the zero bound constraint has been considered to be of doubtful practical importance. The standard Keynesian prescription, as described by Hicks (1937) in the work that introduces the IS–LM model along with the liquidity trap, is to launch expansionary fiscal measures to stimulate the economy. However, the economic crisis in Japan, where the overnight rate has been stuck at zero for about twenty years, and the global economic recession of 2008 generated renewed interest in and triggered debates about the role of fiscal interventions in stimulating an economy. The

existing literature, for instance, provides mixed evidence on the effectiveness of fiscal policy interventions. There are mainly two strands that examine the size of the government spending multiplier: the neoclassical and the new Keynesian models.[5] Using neoclassical models, Aiyagari et al. (1992) and Baxter and King (1993) show that a permanent increase in government purchases, which is financed by "non-distortionary means," causes a negative wealth effect in the economy. In response, households decrease their consumption and increase their labor supply, creating an increase in output. Blanchard and Perotti (2002) employ reduced-form vector autoregressive (VAR) techniques and find that government spending shocks have a small but positive effect on output while tax shocks have a negative effect. Beetsma and Giuliodori (2011) find that government purchases have a small but positive effect in the EU countries.

In a more recent study, Ramey and Zubairy (2018) estimate that US government spending state-dependent multipliers are below unity both during periods of economic slack and when interest rates are at the zero lower bound. On the contrary, Caggiano et al. (2015) and Leeper et al. (2017) find a multiplier larger than one using VAR models and Bayesian prior and posterior analysis, respectively. Canzoneri et al. (2015) document a state-dependent multiplier above two during recessionary periods. Leeper et al. (2010) employ a conventional DSGE model to examine the dynamic responses of fiscal instruments to the level of economic activity and to the level of government debt in the United States. They estimate the fiscal multipliers for output, consumption, and investment and mainly document that, when all the fiscal instruments respond to debt, the multipliers do not exceed one. Fiscal multipliers can also differ across horizons (short versus long run). More importantly, Leeper et al. (2010) note that their study does not take into account the possible interactions between fiscal policy and monetary policy, which could induce dramatic changes in the fiscal multipliers, essential-

[5] For a brief analysis of the neoclassical and the New Keynesian literature on the government spending multiplier, please also see Ramey (2011b).

ly when the monetary policy follows a predetermined set of rules or when the nominal interest rate is at the zero lower bound.

Based on the New Keynesian models, Cogan et al. (2010) document smaller fiscal multipliers that are usually below unity. Krugman (1998) is among the first to study the implications for monetary and fiscal policies in a liquidity trap at the zero lower bound and propose a long-term commitment to a zero nominal interest rate as the optimal solution. Subsequently, Eggertsson and Woodford (2003, 2004) show that keeping the nominal interest rate at the zero lower bound for a long period is an effective policy to generate inflation and stimulate an economy in a liquidity trap. Galí et al. (2007) also obtain small multipliers within a New Keynesian model when employment is demand-determined and workers are always willing to supply optimally, while the multiplier can be two when the marginal propensity to consume is higher than it would be if consumers behaved optimally. Fernandez-Villaverde et al. (2015) argue that the most effective way to study liquidity trap dynamics is to take nonlinearities into account explicitly to analyze the behavior of the New Keynesian model at the zero lower bound.

Eggertsson (2010) proposes a New Keynesian dynamic stochastic general equilibrium (DSGE) model to investigate the effect of government purchases and tax cuts when the zero lower bound becomes binding and the economy experiences deflation and output contraction. The model shows that tax cuts are contractionary while the government spending multiplier can be as high as five in the US economy. The author argues that the main problem in a zero lower bound environment is the insufficient demand. Building on the same New Keynesian model, Denes et al. (2013) observe that the effect of fiscal policy at the zero lower bound can be either contractionary or expansionary depending on the interactions with the expectations about the long-run tax cuts and government purchases. Similarly, Christiano et al. (2011) find that the government spending multiplier can be larger than one in the US economy when the zero lower bound is binding. In a similar vein, Mertens and Ravn (2014) show that, in a li-

quidity trap caused by a self-fulfilling state of low confidence, the government spending multiplier can be larger than one. The results in the study by Correia et al. (2013) indicate that an alternative path to stimulate the US economy at the zero lower bound is to cut taxes rather than to increase government purchases. Finally, Blanchard et al. (2010) evaluate the American Recovery and Reinvestment Plan and suggest that better integration between monetary and fiscal policy is needed when the zero lower bound is reached to escape from a liquidity trap.

3. The Model

In this section, we develop a standard New Keynesian DSGE model to analyze the effect of an increase in government spending and a cut in income tax on output. The model builds on and is similar in spirit to the one introduced by Eggertsson (2010), which is then extended by Denes et al. (2013).

Our model differs from that of Eggertsson (2010) and Denes et al. (2013) in five main aspects: (i) we assume two distinctively different shocks ξ_t in the model when the zero bound is binding: an increase in government spending and a decrease in income taxes; (ii) government spending in our model is an imperfect substitute for private consumption, so we allow an increase in government spending to be followed by an increase in private consumption and vice versa; (iii) our assumption is that households' consumption is a function of – and therefore is affected by – income tax and that households consume goods net of taxes (this is a more realistic approach than the treatment of income tax in the existing literature; temporarily cutting income tax is an example of effective fiscal policy[6]); (iv) the government budget constraint developed by Denes et al. (2013) and the aggregate demand (AD) and aggregate sup-

[6] As analyzed by Eggertsson (2010), a tax cut is helpful not because of its effect on the aggregate supply but because it directly stimulates the aggregate spending. Similarly, a temporary increase in government spending is effective because it directly increases the overall spending in the economy. However, for government spending to be effective in increasing the demand, it has to be directed to goods that are imperfect substitutes with private consumption (such as infrastructure spending). Otherwise, government spending will be offset by cuts in private spending, leaving the aggregate spending unchanged.

ply (AS) developed by Eggertsson (2010) are modified based on our assumption that there are only lump sum and income taxes; and (v) we relax the assumption related to the inflation constraint by allowing for positive inflation in the steady state, and as a result the interest rates are allowed to remain at the zero lower bound not only in the short run but also in the long run, even when the inflationary pressures increase significantly. This allows our model to take into account the zero lower bound commitment proposed by Krugman (1998) and hence to test its effectiveness in accordance with an expansionary fiscal policy.

3.1 The cashless economy

3.1.1 Households

The model works in a cashless economy with uncertainty in period t ≥ 0, where, for simplicity, the only assets traded are one-period riskless bonds, B_t. Within this setting, and as is standard in the New Keynesian literature, there is a continuum of households of measure 1, and the representative household has a set of preferences described over aggregate consumption C_t and maximizes utility, U, as given by

$$U = E_t \sum_{T=t}^{\infty} \beta^{T-1} \xi_T \left[u(C_T + g(G_T) - \int_0^1 v(l_T(j)) d_j \right], \quad (1)$$

where β is a discount factor, ξ_T is a preference shock, $C_T \equiv \left[\int_0^1 c_t(i)^{\theta-1/\theta} di\right]^{\theta/(\theta-1)}$ is the Dixit–Stiglitz aggregate of consumption of each of a continuum of differentiated goods with an elasticity of substitution between varieties equal to $\theta > 1$, $P_t \equiv \left[\int_0^1 p_t(i)^{1-\theta} di\right]^{1/(1-\theta)}$ is the Dixit–Stiglitz price index, and $l_T(j)$ is the quantity supplied of labor l_t of type j. G_T represents the aggregate government spending and is exogenously defined as a Dixit–Stiglitz aggregator of public consumption, but it is not substitutable for private consumption.[7] Each industry j employs an industry-specific type of labor, with its own real wage $W_t(j)$. $u(\cdot)$ and $g(\cdot)$ are increasing concave functions and $v(\cdot)$ an increasing convex function.

[7] Eggertsson (2010) introduces two terms of government spending, G_T^S and G_T^N, that differ in how they enter utility, the first term being perfectly substitutable for private consumption.

Since we do not examine the optimal fiscal policy, the model has two types of taxes: a lump sum tax T_t, which is a residual variable that adjusts over time so that the government budget constraint can always be satisfied, and an income tax τ_t^I on income from both labor and households' claim on firms' profits (e.g. dividends). Income tax plays an important role in our model, since it is used as a tool to identify the effects of a tax cut on the output when calibrating the model. In addition, risk-free bond returns and dividend payments do not have different tax treatment, because identifying the optimal policy is not the focus of this study and therefore a different interpretation does not change any of the results. Households take prices (P_t) and wages (W_t) as given. Consequently, the period budget constraint can be written as:

$$(1+\tau_t^I)P_tC_t + B_t = (1+i_{t-1})B_{t-1} + (1+\tau_t^I)\left[\int_0^1 Z_t(i)di + P_tC_t\int_0^1 W_t(j)l_t(j)dj\right] - P_tT_t,$$

$$t \geq 0 \qquad (2)$$

where $Z_t(i)$ represents the lump sum profits distributed to the households.[8]

3.1.2 Firms

There is a continuum of firms of measure 1, with prices set as described by Calvo (1983). Every period, a firm (i) sets its price and has an equal probability of revising the price with probability $1-\alpha$. In the next phase, a firm uses labor inputs to meet the demand, and for simplicity one unit of labor produces one unit of output. Following Eggertsson (2010) and Denes et al. (2013), we assume that the government distributes its spending on varieties defined as a Dixit-Stiglitz aggregate similar to households consumption; hence, the demand function for good i takes the form of $y_t(i) = Y_t[(p\_t\ (i))/P\_t\ ]^{-\theta}$, with the aggregate output represented as $Y_t \equiv C_t + G_t$. All the output is consumed either by the private sector or by the government. We assume that all the profits are distributed as dividends and that firms seek to maximize their profits net of taxes. Therefore, the profits for these firms are

[8] See also Eggertsson (2010) and Denes et al. (2013) for a similar treatment.

$$Z_t(i) = p_t(i)Y_t\left[\frac{p_t(i)}{P_t}\right]^{-\theta} - W_t(j)Y_t\left[\frac{p_t(i)}{P_t}\right]^{-\theta} \quad (3)$$

where i represents the index for the firm and j represents the index for the industry in which the firm operates. Since a firm can revise and set its price in every time period, we let $0 < \alpha < 1$ be the fraction of industries with prices that remain unchanged in each period. As a result, for any industry that revises its prices in period t, the new price p_t^* will be the same. Therefore, when a firm revises its price, it chooses to maximize the price p_t^* as

$$\max_{p_t^*} E_t\left\{\sum_{T=t}^{\infty}(\alpha\beta)^{T-1}\lambda_T(1-\tau_T^P)[p_t^*Y_T\left(\frac{p_t^*}{P_T}\right)^{-\theta} - W_T(j)Y_T\left(\frac{p_t^*}{P_T}\right)^{-\theta}]\right\}, \quad (4)$$

where λ_T is the marginal utility of the nominal income for the representative household.

3.1.3 Government and central bank policy

Our assumption is that the economy is in a recessionary era and therefore the central bank implements a zero lower bound policy. In this framework, the desired path for nominal interest rates is described extensively by Eggertsson and Woodford (2003). Similarly, we assume that interest rates cannot be negative:

$$i_t \geq 0. \quad (5)$$

We build the government's budget constraint, which is given in Eq. (6), in the spirit of Denes et al. (2013). The main difference is that our model uses two types of taxes:

$$b_t = (1+i_{t-1})b_{t-1}\Pi_t^{-1} + (1-\tau_t^I)Y_t - T_t, \quad (6)$$

where $b_t \equiv \frac{B_t}{P_t}$ is the real value of the government debt and $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ is the gross inflation.

3.1.4 Equilibrium

The model is log-linearized around a constant solution with positive government debt $\bar{b} > 0$ and inflation $\pi_t \geq 0$. It can be solved by an approximation around a steady state. In particular, the consumption Euler equation of the representative household combined with the resource constraint can be approximated to yield

$$\widehat{Y}_t = E_t\widehat{Y}_{t+1} - \sigma(i_t - E_t\pi_{t+1} - r_t^e) + (\widehat{G}_t^N - E_tG_{t+1}^N) + \sigma\chi^I E_t(\hat{\tau}_{t+1}^I - \hat{\tau}_t^I), \quad (7)$$

where i_t is the one-period risk-free nominal interest rate, E_t an expectation operator, and $\hat{G}_t^N$ the percentage changes in government spending from its steady state as a fraction of the steady-state output. The coefficients are $\chi^I > 0$, $\widehat{Y_t} \equiv \log\frac{Y_t}{\bar{Y}}$, and $\widehat{G_t} \equiv \log\frac{G_t}{\bar{Y}}$. Notably, $\hat{\tau}_t^I \equiv \tau_t^I - \bar{\tau}^I$; hence, a 1% increase in government spending will increase the income tax and tax revenues by exactly the same amount. Finally, r_t^e is an exogenous disturbance that varies as a function of shock ξ_t. The coefficients explained above are defined following Eggertsson (2010).

Accordingly, the aggregate supply (AS) is given by

$$\pi_t = \kappa\hat{Y}_t + \kappa\psi\left(\chi^I\hat{\tau}_t^I - \sigma^{-1}\hat{G}_t^N\right) + \beta E_t\pi_{t+1}, \tag{8}$$

where the coefficients $\kappa > 0$, $\psi > 0$, $0 < \beta < 1$, and $\pi_{t+1} > \pi_t > 0$ and the zero bound is such that $i_t \geq 0$.

Following Denes et al. (2013), the government budget constraint can be approximated to yield

$$\frac{\bar{b}}{Y}\hat{b}_t - \frac{\bar{b}}{Y}(1+\bar{r})\hat{b}_{t-1} = \frac{\bar{b}}{\bar{Y}}(1+\bar{r})(\hat{\imath}_{t-1} - \pi_t) + \left(1+\bar{\tau}^i\right)\hat{G}_t^N - \left(\bar{\tau}^I\hat{Y}_t\right) - \hat{\tau}_t^I - \hat{T}_t, \tag{9}$$

where $\hat{b}_t \equiv log\frac{B_t}{P_t} - log\bar{b}$ and $\hat{T}_t \equiv log\frac{T_t}{\bar{Y}}$.

3.1.5 Short-run and long-run policy allocations

To solve the model at the steady state, we introduce three assumptions that are quite common in the literature following the works of Eggertsson (2010) and Denes et al. (2013). We distinguish between short-run and long-run periods in the model. The long run is defined in the model as the period in which the shock, r_t^e, from an increase in government spending or from a decrease in income taxes has moved to the steady state. In the short-run period, the economy is subject to the disturbance shock from the fiscal intervention, which is defined as $r_t^e = r_s^e$, to satisfy the commitment that interest rates will stay at the zero bound.

Assumption 1. In period 0, there is a shock $r_s^e < \bar{r}$ *that reverts to the steady state with probability* $1-\mu$ *in each period. We call the stochastic period in which the shock reverts to the steady state* t_S *and assume that* $(1-\mu)(1-\beta\mu)-\mu\sigma\kappa > 0$.

Accordingly, for the fiscal policy:

Assumption 2. $t_t^I = \hat{G}_t = 0$ *for* $\forall t$ *and future lump sum taxes* $\hat{T}_t$ *are set so that the government budget constraint is always satisfied, as defined in Equation (9), while* $\hat{T}_t = 0$ *for* $\forall\ t < t_S$.

Our assumption for the monetary policy provides a different treatment:

Assumption 3: For nominal interest rates, we consider two cases:

i) Short-term nominal interest rates are set to $i_t = 0$ *so that* $\pi_t = \hat{Y}_t = 0$. *If this requires* $i_t < 0$*, then we assume* $i_t = 0$ *and* π_t *is endogenously determined.*

ii) If positive interest rates are required, there is a locally unique bounded equilibrium with inflation and output such that

$$\pi_t = \pi_S^p \ \forall\ t < t_S \tag{10}$$

$$\hat{Y}_t = \hat{Y}_S^p \ \forall\ t < t_S \tag{11}$$

$$i_t = i_S^p = r_S^e + \varphi_\pi \pi_S + \varphi_y \hat{Y}_S\ > 0 \tag{12}$$

Given *Assumptions 1*, *2*, and *3*, the fiscal policy is perfectly correlated with the shock, since we consider an increase in spending to be followed by an increase in tax revenue and a decrease in income tax to be followed by a decrease in government spending.[9] We focus on the equilibrium at the zero lower bound by looking at the comparative effectiveness of the fiscal policy in the short and the long run when the zero bound is binding. The central bank seeks to stimulate economic growth (output), and inflation thus becomes an endogenous object. Accordingly, *Assumption 3* implies that $\pi_t = \hat{Y}_t$ for $t \geq t_s$ in the short run when the zero bound condition is not binding.

[9] *Assumption 3* is developed and discussed in a more sophisticated way by Eggertsson (2010), with identical policy rules.

As we have discussed in equation (2), a lump sum tax $\hat{\tau}_t$ is used as a residual variable that adjusts over time so that the government budget constraint is always satisfied. Based on this condition and following Denes et al. (2013), we make *Assumption 4* with slightly different tax policy rules in the short run ($0 \leq t \leq t_S$).

Assumption 4: The budget deficit is stabilized after the shock from the increase in government spending or the reduction in income taxes by using the lump sum tax so that we let $\left(\hat{t}_t^I, \hat{G}_t\right) = \left(\hat{t}_t^L, \hat{G}_L\right) = 0$ *for* $\forall\, t \geq t_S$ *and* $\left(\hat{t}_t^I, \hat{G}_t\right) = \left(\hat{t}_S^L, \hat{G}_S\right) = 0$ *for* $\forall\, 0 \leq t \leq t_S$. *The lump sum taxes* $\hat{\tau}_t$ *on dates* $t \geq t_S$ *are set so that the government budget is balanced, while* $\hat{\tau}_t = 0$ *for* $\forall\, 0 \leq t \leq t_S$.

Overall, with respect to the above-mentioned assumptions, our model satisfies the following equations:

$$(1-\mu)\hat{Y}_S = -\sigma i_S + \sigma\mu\pi_s + \sigma r_S^e + (1-\mu)\hat{G}_S - \sigma\chi^I(1-\mu)\hat{\tau}_S^I, \tag{13}$$

$$\pi_S = \kappa\hat{Y}_S + \kappa\psi\left(\chi^I\hat{\tau}_S^I - \sigma^{-1}\hat{G}_S\right) + \beta\mu\pi_S, \tag{14}$$

$$\hat{D}_S = \frac{\bar{b}}{Y}(1+\bar{\imath})(i_S - \pi_S) + (1+\bar{\tau}^I)\hat{G}_S - \left(\bar{\tau}^I\hat{Y}_S\right) - \hat{\tau}_S^I - \frac{\bar{C}}{\bar{Y}}\hat{\tau}_S^I, \tag{15}$$

Next, the following two *propositions* are introduced to compute the government spending and income tax cut multipliers.

Proposition 1: Supposing that Assumptions 1, 3, and 4 hold, the output multiplier for government spending with a positive and zero interest rate is

$$\frac{\Delta\hat{Y}_S}{\Delta\hat{G}_S} = \begin{cases} \psi\sigma^{-1} > 0 & if \quad i_S > 0\ (i.e.\ r_S^e > 0) \\ \dfrac{(1-\mu)(1-\beta\mu) - \mu\kappa\psi}{(1-\mu)(1-\beta\mu) - \sigma\mu\kappa} > 1 & if \quad i_S = 0\ (i.e.\ r_S^e < 0) \end{cases}$$

Accordingly, the proposition can be modified so that the interest rates remain at the zero lower bound even when government spending produces a significant increase in output.

Proposition 2: Supposing that Assumptions 1, 3, and 4 hold, the output multiplier for income tax cuts with a positive and zero interest rate is

$$\frac{\Delta \hat{Y}_S}{\Delta \hat{\tau}_S^I} = \begin{cases} -\chi^I \psi > 0 & if \quad i_S > 0 \ (i.e.\ r_S^e > 0) \\ -\sigma \chi^I \dfrac{\mu\kappa\sigma\psi}{(1-\mu)(1-\beta\mu)-\sigma\mu\kappa} > 1 & if \quad i_S = 0 \ (i.e.\ r_S^e < 0). \end{cases}$$

Propositions 1 and *2* parameterize the model and provide closed-form solutions for the effect on the output of a one-percent change in each of the fiscal instruments (increase in government spending and income tax cuts).[10]

3.2 Calibration

To calibrate the DSGE model, we map the equilibrium conditions in Section 3.1 to set up a state-space model. Due to the small sample size, applications to the big four countries in the euro area are more suitable for VAR models. Therefore, we follow the recommendation of Christiano et al. (2006) and use an SVAR model to calibrate and validate a theoretical DSGE model. We build on the approach of Blanchard and Perotti (2002) and Beetsma and Giuliodori (2011) to set up a reduced-form SVAR model that is informationally sufficient for the two structural fiscal shocks (see also Forni et al., 2014 for further discussions). Initially, we consider the following specification:

$$Y_t = \delta E_t Y_{t+1} + k_t + \xi_t + \varepsilon_t \qquad (16)$$

where Y_t is a forward-looking process representing the output, which is affected by a stationary process k_t, an expansionary fiscal policy shock ξ_t, and $\varepsilon_t \sim N\ i.i.d.$, which captures the non-fiscal spending shocks affecting the output. We allow the fiscal multipliers to differ under a slightly modified policy cycle scheme with an increase in government spending or a decrease in income taxes.

The effect of expansionary fiscal spending shocks to the economy is not linear and changes over time from the short run to the medium run, allowing for two regimes. In the model, government purchases are represented by G, output by Y, country-specific cyclically adjusted net taxes (i.e. tax revenues) by TR, and the interest rate by r. These variables are the

[10] Eggertsson (2010) and Denes et al. (2013) use similar approaches with slightly different policy rules.

endogenous variables, enter into the vector $[G, Y, TR, r]$, and are ordered according to a lower-triangular Cholesky decomposition.[11] All the variables are in natural logarithms, except for the interest rate, which is in percentages. In particular, the structural shock ξ_t takes the following form:

$$\xi_t = \Omega\left(A_t - E(A_t|\ A^{t-1})\right) \tag{17}$$

where A_t is the vector of our observed macroeconomic variables and A^{t-1} the history of A_t up to the time $t-1$. $A_t - E(A_t|\ A^{t-1})$ thus represents the forecast error and Ω the rotation matrix. Let $\gamma \in \Gamma$ be the vector of parameters of the log-linearized DSGE model, which are unknown and are to be estimated. We combine a likelihood function with a prior distribution to obtain a posterior distribution of the model parameters. The log-linearized DSGE model can be expressed as follows (see, e.g., Anderson, 2010; Del Negro and Schorfheide, 2004; Ghent, 2009):

$$\Omega_{-1}\xi_{t-1} + \Omega_0\eta_t\Omega_1 E_t\eta_{t+1} = D\xi_t, \tag{18}$$

where ξ_t is a q-dimensional vector with *i.i.d.* standard normal structural shocks so that $\xi_t \sim N(0, I_q)$ and η_t is an r-dimensional vector of model variables, defined as deviations from the steady state. The matrices $\Omega_i(r\times r)$, with $i = -1, 0, 1$ and D $(r\times q)$, are functions of γ.

A unique and convergent solution of Equation (18) exists at a particular value of γ so that the model variables are represented in a state-space model in an SVAR system in the following two equations (Sargent, 1989):

$$\eta_t = F\xi_{t-1} + B\eta_t \tag{19}$$

where F $(r\times r)$ and B $(r\times q)$ are uniquely determined by γ. We denote the observed variables by y_t, in an n-dimensional vector, and the measurement error ε_t is linked to the model variables η_t as

[11] To take into account the cross-country heterogeneity in the response of net taxes to changes in output, cyclically adjusted net taxes are more appropriate than unadjusted net taxes (Alesina et al., 2002; Beetsma and Giuliodori, 2011).

$$y_t = \lambda^{\mu} + \Phi' \eta_t + \varepsilon_t \quad (20)$$

Note that ε_t is assumed to be *i.i.d*. Gaussian with mean zero and covariance matrix R, while λ^{μ} represents the population mean at the steady state of y_t conditional on γ. The measurement errors and the shocks are independent, and matrices R and Φ are uniquely determined by γ.

4. Empirical findings

4.1 Sample data

We follow Romer and Romer's (2010) approach to build our comparable data set for the four largest eurozone economies. The data set covers the period from March 2002 to December 2015 and is constructed from official documents provided by Eurostat, the European Central Bank, and Datastream International. In particular, we use quarterly data of the gross domestic product (GDP), government debt, the budget balance, discretionary government spending and investments, private and household consumption, and tax revenue collections.

Figure 1 depicts the fiscal position of the four largest eurozone economies from 2002 to 2015. The fiscal position is readjusted annually to reflect the real deficit or surplus reported by the countries. We observe that the best-performing country is Germany, with the largest deficit of about 4% in the aftermath of the financial crisis of 2008 (i.e., the period from 2008 to 2010). Since 2012, Germany has achieved a marginal fiscal surplus. We also observe that Spain had a fiscal surplus until the crisis of 2008, when government interventions caused an initial deficit of 10%. Italy and France have a deficit of 3% and 5%, respectively.

[Please insert Figure 1 about here]

In the following, we successively discuss the results related to the effect of government purchases and tax cut shocks on all four economies and the estimate for the multipliers for each of the four economies.

4.2 Impulse responses

The set of endogenous variables in the baseline structural VAR consists of the government spending G (the sum of government consumption and investment), cyclically adjusted net taxes (with country-specific cyclical adjustment) TR, output (GDP) Y, and long-run nominal interest rate r. The identification is based on a lower-triangular Cholesky decomposition according to this particular ordering. Since we focus on impulse responses to government purchases shocks, the relative ordering of the variables does not affect the impulse responses, as these variables are all ordered after government purchases (see also Christiano et al., 2006 for similar treatment).

[Please insert Table 1 about here]

[Please insert Figure 2 about here]

Table 1 reports the impulse responses of macroeconomic variables to a 1% increase in government purchases as a share of the GDP. The immediate effect of the expansionary fiscal policy on all the variables is positive for all the economies under consideration. This impact remains significant and apparent until five years after the fiscal shock for most variables. More precisely, the output immediately rises following the shock, and the increases range from 1.84% (Germany) to 2.18% (Spain). The largest response is observed one year later with output increases between 2.13% (Germany) and 2.52% (France). The cyclically adjusted net taxes only react significantly and immediately to the fiscal shock, with small effects ranging from 0.36% (Germany) to 0.49% (Italy) and disappearing one year after the shock. The response of private consumption is smaller than 1% for all the countries. Noticeably, the long-run interest rate exhibits a significant upward trend, implying the existence of inflationary pressures in the years following the positive shock to government spending. This trend can be explained by the fact that monetary policymakers have to raise interest rates to control inflationary pressures. In Germany, the interest rates increase to 3.51% five years after the shock. Regarding the budget balance (i.e., fiscal deficit–surplus), it responds positively to the

increase in government spending for all the economies, indicating that this fiscal policy triggers the budget deficit.

Figure 2 illustrates the baseline (overall average) impulse responses of the output, private consumption, and budget balance to a 1% increase in government spending as a share of the GDP. The orange lines represent the confidence bands, while the red line shows the aggregate effect on the economies of the four eurozone countries after 5,000 Monte Carlo simulations that confirm our results presented in Table 1. The linear dashed trend line exhibits the trend caused by the fiscal shock. It should be noted that the government budget is allowed to deviate from the budget constraint in the Monte Carlo simulation to show the real effect that this policy has by producing a significant deficit without redistributing lump sum taxes to balance the budget.

[Please insert Table 2 about here]

The impulse responses to a 1% decrease in taxes as a share of the GDP are presented in Table 2. The results show that the effect of the tax cut policy on the economy is smaller than in the case of a positive shock to government spending. As expected, the cyclically adjusted net taxes experience a significant and immediate decrease. The effect of tax cuts on the output is positive and significant, and it lasts until five years after the shock for all the countries. The largest and smallest immediate impulse responses are found in Germany (1.47%) and in Spain (0.77%). As for the other variables, they respond positively and significantly to the reduction in taxes, except for the budget balance, which improves (i.e., a reduction of the budget deficit) after the shock given its significant decreases.

[Please insert Table 3 about here]

Table 3 provides the impulse responses to a government spending shock at the zero lower bound monetary policy and a long-term commitment to future high inflation, as pro-

posed by Krugman (1998).[12] As we can see, the results obtained are broadly similar to those in Table 2 with respect to the tax cut policy in that the fiscal shock at the zero lower bound interest rates produces positive responses from all the variables with the exception of the net taxes and budget balance. However, the magnitude of the shock effects is much greater. A close look at the results shows that the output increases significantly for all the countries and its responses to the shock remain at a high level even five years later. The immediate increase in the output ranges from 3.57% (Spain) to 4.11% (Germany). The largest output increase is found one year after the shock and reaches 4.08% in Spain, 4.24% in Italy, 4.39% in France, and 4.67% in Germany. It is also important to note that the combination of the fiscal expansionary and the zero lower bound policy cause a significant increase in the long-run interest rate just after the shock, which helps control inflationary pressures. As expected, due to the fiscal expansionary policy with increases in government spending, the budget balance is negatively affected in the short run for all the economies. On the contrary, in the long run, the benefits from stimulating economic growth ameliorate the effect on the government budget. Notably, an interesting picture is uncovered for the effect on the cyclically adjusted net taxes. More precisely, the initial net taxes are affected negatively, but in the long run they have a positive trend, indicating an increase in the collection of taxes.

Overall, our results reveal that the strongest effect on the economy during the recessionary period is achieved by an expansionary fiscal policy driven by an increase in government spending associated with a long-term commitment to keeping the interest rates at the zero lower bound. This policy also triggers greater inflationary pressures.

4.3 Time and trend effects

As a robustness check for the results of the baseline models, we also use annual data to tackle the anticipation effects in our quarterly data set. Concretely, Tables 4, 5, and 6 report the im-

[12] In this case, the short-term interest rates are not allowed to change due to inflationary pressures, so the condition $r_t^e = r_s^e$ described in Section 3.2 is satisfied.

pulse responses to fiscal shocks (i.e., an increase in government spending, tax cuts, and an increase in government spending combined with a long-term commitment to keeping the interest rate at the zero lower bound, respectively) using annual data with quadratic time and trend effects in the regression. This adjustment allows the model to take into consideration the trend of the economy and is in line with the approach used in the extant literature (e.g., Beetsma and Giuliodori, 2011; Caggiano et al., 2015).

Importantly, the impulse responses closely resemble to those from the baseline estimation. Specifically, the results are similar if we compare the shock effects between the quarterly data without quadratic time and trend effects (Table 1, Table 2, and Table 3) with the annual data (Table 4, Table 5, and Table 6). The unique difference is the smaller magnitude of the shock effects for all cases when the time and trend effects are introduced into the SVAR model. The results also confirm that the combined effect on the output from a government spending shock and a long-term commitment to keeping the interest rate at the zero lower bound is stronger than the effect caused by a pure government spending or tax cut policy.

[Please insert Tables 4, 5, and 6 about here]

More precisely, the results in Table 4 indicate that a positive shock to government spending triggers a significant and immediate increase in the economic output, with values ranging from 0.82% (France) to 0.93% (Germany), compared with values from 1.84% (Germany) to 2.18% (Spain) in Table 1. The growth effect of the fiscal shock remains significant until five years afterwards. The shock effect is also the same for net taxes, private consumption, long-run interest rates, and the budget balance. As regards Table 5, the implementation of the tax cut policy generates a positive and immediate response from the output, but the effect is not necessarily smaller than the government spending shock shown in Tables 1 and 2. This finding suggests that the historical paths of an economy matter for the shock absorption and growth recovery following the stimulus policies. Countries with a better fiscal balance

could recover and escape from the liquidity trap more easily. With the tax cut-driven policy, the budget balance improves immediately, as it responds negatively and significantly to the shock. Last but not least, Table 6 confirms the superiority of the government spending shock under the zero lower bound commitment for a long period in terms of the growth effect and fiscal balance improvement, owing to the high economic growth rate and tax collections. The inflationary pressure is observed immediately and becomes challenging only in the long run, but the pressure is less than in the case of a stimulus policy based on government spending.

4.4 The effect of a large government debt

In addition, we simulate a scenario in which the budget deficit of the four eurozone countries under consideration, measured by the budget balance as a share of the GDP, is restricted not to exceed 3% during the first year of the implementation of the fiscal stimulus policy due to existing high levels of government debt. The 3% deficit refers to the threshold level of the Maastricht Treaty. To achieve this, we impose an increase in the tax rate whenever this condition is binding to keep the deficit at 3%. This systematic response is similar in spirit to that of Beetsma and Giuliodori (2011).

[Please insert Tables 7, 8, and 9 about here]

Tables 7, 8, and 9 report the results obtained from the impulse responses when the system is shocked respectively by an increase in government spending, tax cuts, and a combination of government spending and long-term commitment at the zero lower bound. We mainly find that the impulse responses of system variables to fiscal shocks are essentially consistent with the ones provided by the baseline model (i.e., the results of Tables 1, 2, and 3). However, the effects on the output are smaller, and some countries would be able to reduce their budget deficit two years after a fiscal shock affecting government spending (i.e., the cases of France, Italy, and Spain). The fiscal shock based on government spending together with long-term zero lower bound interest rates is still found to be the best policy op-

tion, as it produces the highest growth rate and allows the sample countries to improve their fiscal situation significantly in the long run.

4.5 The fiscal multipliers

One way to assess empirically the effectiveness of different fiscal policy options regarding economic growth is to compare the fiscal multipliers across policy options, that is, the effect of a change in government spending (ΔGs) or in tax cuts (Δtc) on output variations (ΔY). We do so by computing the fiscal multipliers in four different scenarios: i) an increase in government spending; ii) an increase in government spending under the assumption of a high public debt level (the restriction of a government deficit lower than 3%); iii) tax cuts; and iv) tax cuts under the assumption of a high public debt level. These scenario-based multipliers are computed for two distinct environments: i) the nominal interest rate responds to the implemented fiscal shocks and thus increases in the long run; and ii) the nominal interest rate is kept at the zero lower bound with a long-term commitment to generating future inflation.

The results, reported in Table 10, show that the government spending fiscal multiplier has the strongest impact on economic growth. It ranges from 1.09 (France) to 1.173 (Germany) within the positive interest rate environment. The multiplier is much lower when tax cuts are used to stimulate the economy, as it varies between 0.201 (Spain) and 0.639 (Germany). Regarding the associated multipliers, both fiscal policies exert very small effects on the output when the constraint of a 3% budget deficit at most is introduced, suggesting that a high level of public debt could prevent the economy from achieving a quick recovery. The output effect of fiscal policies improves significantly when they are associated with the zero lower bound monetary policy, particularly in the case of government spending with fiscal multipliers above 1.8, for all the countries. Taken together, the insights from the fiscal multipliers show evidence of greater effectiveness of a government spending shock than the tax cut policy, regardless of the interest rate environment. More importantly, the effectiveness of the fis-

cal stimulus policy by increasing government spending is the greatest when it is combined with a long-term commitment to zero lower bound interest rates.

[Please insert Table 10 about here]

[Please insert Figure 3 about here]

We depict the temporal paths of some estimated multipliers in Figure 3. As it can be seen, the government spending fiscal shock multiplier at the zero lower bound (red line) has the strongest output effect on stimulating the economy, followed by the tax cut policy (red line). The pink line shows the magnitude of the government spending multiplier when taking into account a large government debt.

5. Conclusion

In this article, we examine the effect of government spending and tax cut shocks at the zero lower bound on the economic growth of the big four eurozone economies. Our theoretical framework is built on a New Keynesian dynamic stochastic general equilibrium (DSGE) model proposed by Eggertsson (2010) and extended by Denes et al. (2013). This model allows for a commitment to a constant nominal interest rate over the long run, and it is calibrated by employing an SVAR approach to the sample economies.

Our main results show that fiscal shocks through government spending are more effective than a tax cut policy in stimulating economic growth, particularly when there is a long-term commitment to keeping interest rates at the zero lower bound. Indeed, the estimated government spending multipliers are greater than 1.8 for all the countries when the zero lower bound is binding, and the nominal interest rates do not respond to fiscal shocks. This finding implies that the implementation of a government spending program can stabilize an economy in a time-consistent way with a positive long-run effect on the output and an improvement of the fiscal situation (a reduction of the budget deficit). Importantly, the short-

term effect on the budget balance can be offset and improved five years after the implementation of this policy. The increase in government spending creates significant inflationary pressures in the medium and long run. It is worth noting that government spending programs could also be useful for counteracting the deflation experienced in eurozone economies at the zero lower bound. On the contrary, tax cuts are found to have a smaller effect on the output; therefore, an alternative policy with tax cuts that aims to expand the supply does not have the same power with zero lower bound interest rates. Finally, we find that a large government debt significantly diminishes the magnitude of both government spending and tax cut multipliers, rendering these policies ineffective when an unconventional monetary policy reaches its limits.

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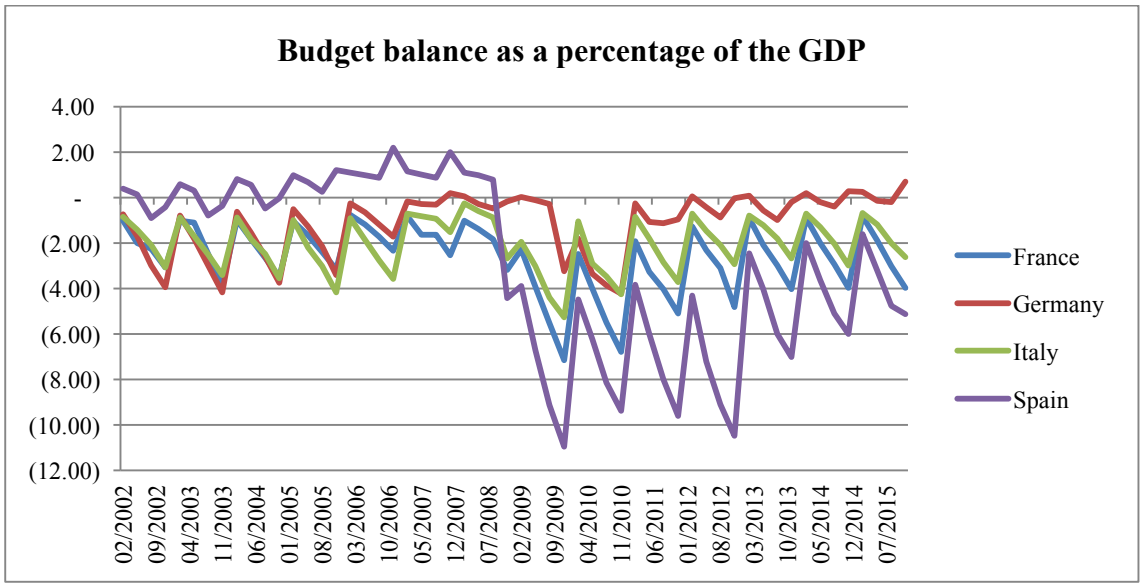
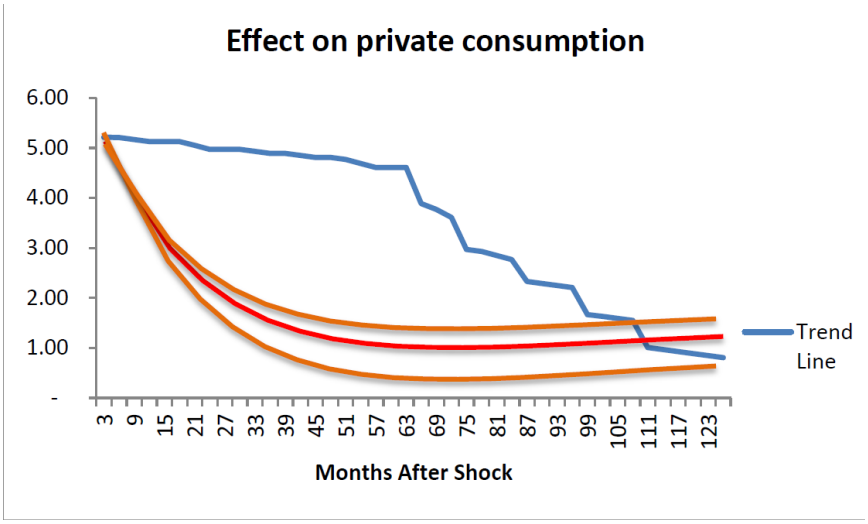
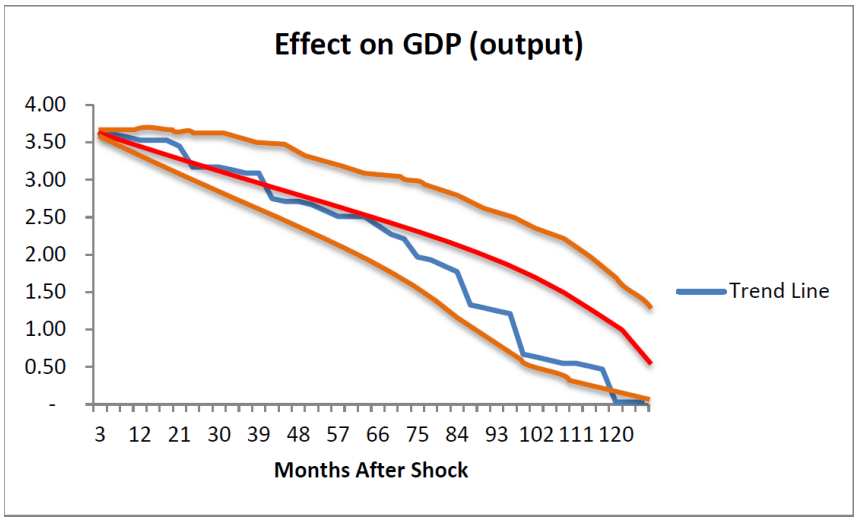


Figure 1. Budget balance as a percentage of the GDP
Notes: The figure exhibits quarterly changes in the budget balance for the four eurozone economies from 2002 to 2015.





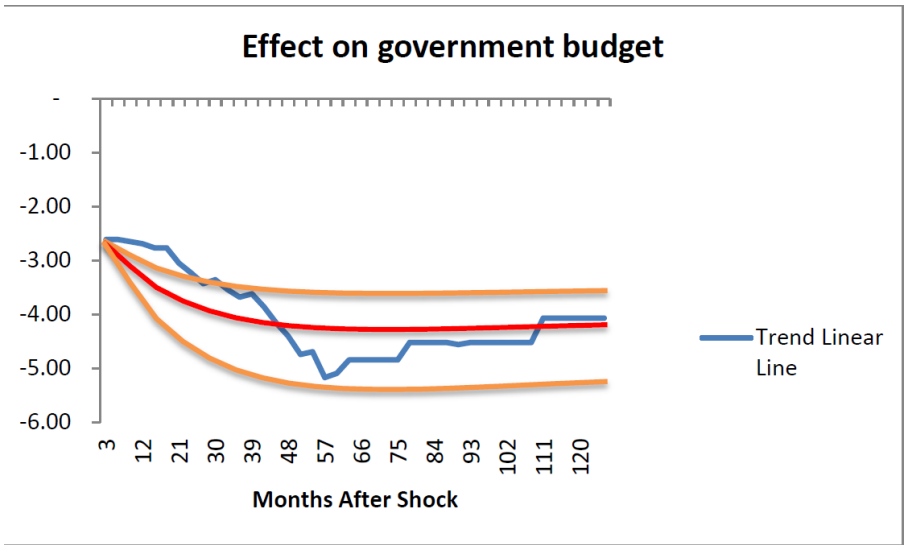


Figure 2. Overall average impulse responses of the output, private consumption, and budget balance to a 1% increase in government purchases as a share of the GDP

Notes: The confidence bands (the light blue lines) are the fifth and the ninety-fifth percentiles from Monte Carlo simulations based on 5000 replications. The red line provides the median estimation over the replications. The solid blue line shows the trend effects of fiscal shocks on the variables under consideration.

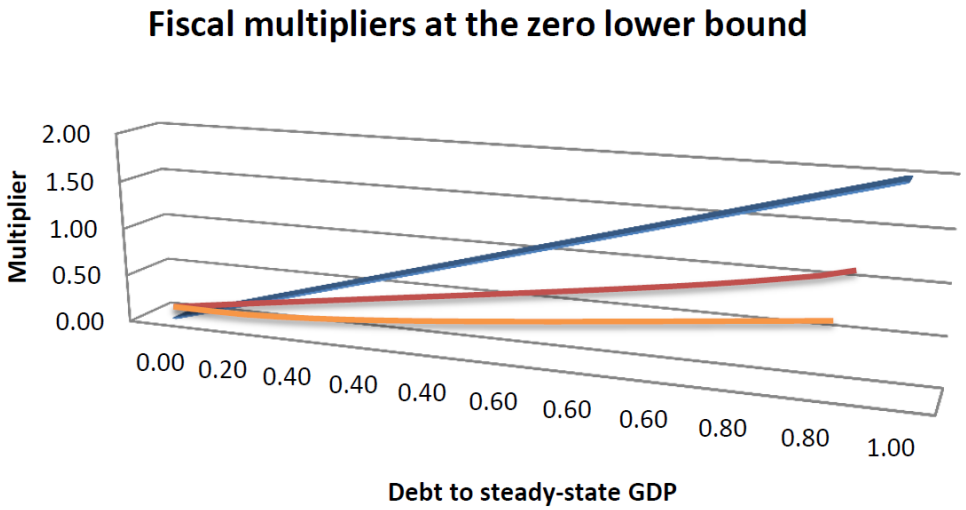


Figure 3. Cumulative estimation of the fiscal multipliers
Notes: The light blue line shows the government spending multiplier. The bold blue line shows the trend of the fiscal spending multiplier. The red line shows the tax cut multiplier, and the pink line shows the magnitude of the government spending multiplier under the hypothesis of a large government debt. The multipliers are plotted against the debt to steady-state GDP ratio to show that as debt increases so does the multiplier (blue line), but a large government debt renders a fiscal expansionary policy ineffective (orange line).

Table 1. Responses to a fiscal shock of a 1% increase in government spending as a share of the GDP – Baseline model

	Impact effect	After one year	After three years	After five years
Baseline – France				
Output	2.06*	2.52*	1.83*	0.61*
Net taxes	0.47*	0.66	0.37	0.19
Government purchases	0.90*	1.08*	0.30*	0.09*
Private consumption	0.58*	0.82*	0.31*	0.14*
Long-run interest rate	2.47*	0.84	2.32*	2.98*
Budget balance/GDP	0.26*	0.12*	0.34*	0.72*
Baseline – Germany				
Output	1.84*	2.13*	1.66*	0.57*
Net taxes	0.36*	0.52	0.28	0.10
Government purchases	0.96*	1.10*	0.42*	0.10*
Private consumption	0.54*	0.79*	0.35*	0.18*
Long-run interest rate	2.78*	0.91	2.75*	3.51*
Budget balance/GDP	0.40*	0.27*	0.50*	0.81*
Baseline – Italy				
Output	2.14*	2.47*	1.92*	0.71*
Net taxes	0.49*	0.68	0.37	0.21
Government purchases	0.92*	1.19*	0.35*	0.11*
Private consumption	0.66*	0.90*	0.37*	0.15*
Long-run interest rate	2.33*	0.52	2.00	3.16*
Budget balance/GDP	0.25*	0.09*	0.38*	0.78*
Baseline – Spain				
Output	2.18*	2.48*	1.97*	0.79*
Net taxes	0.48*	0.71	0.40	0.14
Government purchases	0.93*	1.24*	0.36*	0.09*
Private consumption	0.68*	0.94*	0.41*	0.19*
Long-run interest rate	2.37*	0.61	2.19	3.11*
Budget balance/GDP	0.30*	0.13*	0.40*	0.80*

Notes: * denotes statistical significance at the 10% level. The impulse responses are expressed as a percentage of the underlying variable, except for the long-run interest rate, which is in basis points, and the budget balance to GDP ratio, which is expressed as a percentage of the GDP.

Table 2. Responses to a fiscal shock of a 1% decrease in taxes as a share of the GDP – Baseline model

	Impact effect	After one year	After three years	After five years
Baseline – France				
Output	1.24*	1.35*	0.66*	0.18*
Net taxes	–0.78*	–0.51	0.07	0.22
Government purchases	0.81*	0.94*	0.35*	0.10*
Private consumption	0.43*	0.51*	0.11*	0.07*
Long-run interest rate	0.03*	0.04	0.02	0.00*
Budget balance/GDP	–0.26*	–0.34*	–0.13*	–0.05*
Baseline – Germany				
Output	1.47*	1.83*	0.70*	0.24*
Net taxes	–0.85*	–0.74	0.02	0.30
Government purchases	1.02*	1.20*	0.52*	0.24*
Private consumption	0.46*	0.55*	0.18*	0.08*
Long-run interest rate	0.05*	0.07	0.03*	0.02
Budget balance/GDP	–0.31*	–0.42*	–0.18*	–0.10*
Baseline – Italy				
Output	1.02*	1.26*	0.51*	0.04*
Net taxes	–0.59*	–0.45	0.06	0.23
Government purchases	0.70*	0.76*	0.25*	0.08*
Private consumption	0.22*	0.30*	0.08*	0.02*
Long-run interest rate	0.02*	0.03	0.01	0.01
Budget balance/GDP	–0.24*	–0.33*	–0.12*	–0.03*
Baseline – Spain				
Output	0.77*	0.91*	0.33*	0.01*
Net taxes	–0.52*	–0.40	0.06	0.24
Government purchases	0.53*	0.62*	0.11*	0.02*
Private consumption	0.18*	0.24*	0.05*	0.01*
Long-run interest rate	0.01*	0.02	0.00	0.00
Budget balance/GDP	–0.22*	–0.28*	–0.07*	–0.01*

Notes: * denotes statistical significance at the 10% level. The impulse responses are expressed as a percentage of the underlying variable, except for the long-run interest rate, which is in basis points, and the budget balance to GDP ratio, which is expressed as a percentage of the GDP.

Table 3. Responses to a government spending shock at the zero lower bound policy with long-term commitment (Krugman, 1998) – Baseline model

	Impact effect	After one year	After three years	After five years
Baseline – France				
Output	4.01*	4.39*	3.75*	2.43*
Net taxes	–0.53*	–0.48	0.26	0.30
Government purchases	1.64*	1.96*	1.35*	0.47*
Private consumption	1.28*	1.59*	0.94*	0.38*
Long-run interest rate	1.95*	0.46	2.08*	2.61*
Budget balance/GDP	–0.73*	–0.62*	–0.47*	–0.28*
Baseline – Germany				
Output	4.11*	4.67*	3.92*	2.86*
Net taxes	0.29*	–0.05	0.36	0.41
Government purchases	2.01*	2.42*	1.80*	0.93*
Private consumption	1.43*	1.70*	0.97*	0.45*
Long-run interest rate	2.37*	0.94	2.40*	3.36*
Budget balance/GDP	–0.46*	–0.58*	–0.39*	–0.24*
Baseline – Italy				
Output	3.89*	4.24*	3.56*	1.94*
Net taxes	–1.20*	–0.67	–0.21	0.11
Government purchases	1.48*	1.72*	1.18*	0.30*
Private consumption	1.12*	1.36*	0.72*	0.31*
Long-run interest rate	1.97*	0.29	1.56	3.00*
Budget balance/GDP	–1.03*	–1.14*	–0.72*	–0.36*
Baseline – Spain				
Output	3.57*	4.08*	3.10*	1.53*
Net taxes	–1.48*	–1.02	–0.44	–0.26
Government purchases	1.10*	1.46*	0.95*	0.20*
Private consumption	1.03*	1.20*	0.62*	0.28*
Long-run interest rate	1.88*	0.21	1.14	2.76*
Budget balance/GDP	–1.28*	–1.33*	–0.92*	–0.55*

Notes: * denotes statistical significance at the 10% level. The impulse responses are expressed as a percentage of the underlying variable, except for the long-run interest rate, which is in basis points, and the budget balance to GDP ratio, which is expressed as a percentage of the GDP.

Table 4. Responses to a fiscal shock of a 1% increase in government spending as a share of the GDP – Quadratic time effects and trends

	Impact effect	After one year	After three years	After five years
Quadratic time effects and trends – France				
Output	1.97*	2.28*	1.70*	0.54*
Net taxes	0.42*	0.61	0.33	0.15
Government purchases	0.82*	1.00*	0.27*	0.08*
Private consumption	0.51*	0.76*	0.26*	0.11*
Long-run interest rate	1.85*	0.51	1.70*	2.59*
Budget balance/GDP	0.20*	0.07*	0.29*	0.41*
Quadratic time effects and trends – Germany				
Output	1.71*	2.01*	1.62*	0.54*
Net taxes	0.34*	0.50	0.27	0.10
Government purchases	0.93*	1.08*	0.40*	0.09*
Private consumption	0.52*	0.77*	0.31*	0.16*
Long-run interest rate	2.00*	0.68	1.84*	2.21
Budget balance/GDP	0.37*	0.24*	0.45*	0.76*
Quadratic time effects and trends – Italy				
Output	2.02*	2.40*	1.88*	0.63*
Net taxes	0.44*	0.61	0.34	0.17
Government purchases	0.88*	1.07*	0.30*	0.08*
Private consumption	0.61*	0.80*	0.33*	0.11*
Long-run interest rate	1.98*	0.36	1.59	2.48*
Budget balance/GDP	0.22*	0.02*	0.30*	0.71*
Quadratic time effects and trends – Spain				
Output	2.04*	2.44*	1.91*	0.65*
Net taxes	0.46*	0.67	0.36	0.12
Government purchases	0.91*	1.20*	0.33*	0.06*
Private consumption	0.62*	0.90*	0.37*	0.16*
Long-run interest rate	2.01*	0.42	1.65	2.53*
Budget balance/GDP	0.25*	0.01*	0.26*	0.51*

Notes: * denotes statistical significance at the 10% level. The impulse responses are expressed as a percentage of the underlying variable, except for the long-run interest rate, which is in basis points, and the budget balance to GDP ratio, which is expressed as a percentage of the GDP.

Table 5. Responses to a fiscal shock of a 1% decrease in taxes as a share of the GDP – Quadratic time effects and trends

	Impact effect	After one year	After three years	After five years
Quadratic time effects and trends – France				
Output	1.06*	1.12*	0.60*	0.13*
Net taxes	–0.86*	–0.59	0.01	0.20
Government purchases	0.74*	0.90*	0.31*	0.08*
Private consumption	0.38*	0.43*	0.09*	0.05*
Long-run interest rate	0.03*	0.03	0.02	0.00*
Budget balance/GDP	–0.34*	–0.45*	–0.18*	–0.09*
Quadratic time effects and trends – Germany				
Output	1.30*	1.57*	0.61*	0.22*
Net taxes	–0.89*	–0.75	0.01	0.24
Government purchases	0.95*	1.12*	0.48*	0.21*
Private consumption	0.42*	0.50*	0.12*	0.03*
Long-run interest rate	0.03*	0.03	0.02*	0.01
Budget balance/GDP	–0.35*	–0.48*	–0.19*	–0.12*
Quadratic time effects and trends – Italy				
Output	0.94*	1.10*	0.45*	0.03*
Net taxes	–0.62*	–0.47	0.01	0.20
Government purchases	0.63*	0.71*	0.20*	0.04*
Private consumption	0.18*	0.25*	0.04*	0.01*
Long-run interest rate	0.02*	0.02	0.01	0.01
Budget balance/GDP	–0.29*	–0.38*	–0.16*	–0.09*
Quadratic time effects and trends – Spain				
Output	0.68*	0.80*	0.27*	0.00*
Net taxes	–0.59*	–0.51	0.01	0.10
Government purchases	0.48*	0.55*	0.07*	0.01*
Private consumption	0.14*	0.19*	0.03*	0.01*
Long-run interest rate	0.01*	0.01	0.00	0.00
Budget balance/GDP	–0.29*	–0.36*	–0.04*	–0.01*

Notes: * denotes statistical significance at the 10% level. The impulse responses are expressed as a percentage of the underlying variable, except for the long-run interest rate, which is in basis points, and the budget balance to GDP ratio, which is expressed as a percentage of the GDP.

Table 6. Responses to a government spending shock at the zero lower bound policy with long-term commitment (Krugman, 1998) – Quadratic time effects and trends

	Impact effect	After one year	After three years	After five years
Quadratic time effects and trends – France				
Output	3.92*	4.19*	3.61*	2.20*
Net taxes	–0.59*	–0.52	0.21	0.27
Government purchases	1.58*	1.89*	1.31*	0.34*
Private consumption	1.15*	1.42*	0.86*	0.30*
Long-run interest rate	1.19*	0.21	0.90*	1.75*
Budget balance/GDP	–0.76*	–0.68*	–0.53*	–0.34*
Quadratic time effects and trends – Germany				
Output	4.02*	4.38*	3.76*	2.29*
Net taxes	0.23*	–0.09	0.21	0.38
Government purchases	1.75*	2.10*	1.54*	0.76*
Private consumption	1.23*	1.50*	0.92*	0.36*
Long-run interest rate	1.20*	0.23	0.97*	1.90*
Budget balance/GDP	–0.41*	–0.44*	–0.31*	–0.13*
Quadratic time effects and trends – Italy				
Output	3.61*	4.02*	3.37*	1.70*
Net taxes	–1.39*	–0.74	–0.28	0.02
Government purchases	1.32*	1.48*	0.88*	0.19*
Private consumption	0.90*	1.06*	0.63*	0.27*
Long-run interest rate	1.12*	0.16	0.67	1.28*
Budget balance/GDP	–1.48*	–1.82*	–0.95*	–0.61*
Quadratic time effects and trends – Spain				
Output	3.30*	3.87*	2.96*	1.11*
Net taxes	–1.82*	–1.45	–0.78	–0.44
Government purchases	0.91*	1.20*	0.76*	0.17*
Private consumption	0.82*	1.01*	0.53*	0.20*
Long-run interest rate	1.06*	0.12	0.61	1.23*
Budget balance/GDP	–1.53*	–1.89*	–0.98*	–0.72*

Notes: * denotes statistical significance at the 10% level. The impulse responses are expressed as a percentage of the underlying variable, except for the long-run interest rate, which is in basis points, and the budget balance to GDP ratio, which is expressed as a percentage of the GDP.

Table 7. Responses to a fiscal shock of a 1% increase in government spending as a share of the GDP under the hypothesis of a large government debt

Budget deficit < 3%	Impact effect	After one year	After three years	After five years
Anticipated effects – France				
Output	1.12*	1.36*	0.62*	0.10*
Net taxes	0.34*	0.52	0.21	0.11
Government purchases	0.76*	0.93*	0.23*	0.06*
Private consumption	0.45*	0.70*	0.22*	0.09*
Long-run interest rate	1.76*	0.40	1.52*	2.28*
Budget balance/GDP	0.07*	–0.23*	0.01*	0.30*
Anticipated effects – Germany				
Output	0.98*	1.17*	0.60*	0.14*
Net taxes	0.29*	0.42	0.23	0.08
Government purchases	0.87*	0.98*	0.34*	0.07*
Private consumption	0.48*	0.72*	0.25*	0.12*
Long-run interest rate	1.83*	0.44	1.52*	2.01
Budget balance/GDP	0.30*	0.20*	0.41*	0.72*
Anticipated effects – Italy				
Output	1.23*	1.62*	0.85*	0.19*
Net taxes	0.34*	0.51	0.24	0.13
Government purchases	0.81*	0.92*	0.27*	0.06*
Private consumption	0.58*	0.74*	0.29*	0.09*
Long-run interest rate	1.64*	0.28	1.33	2.18*
Budget balance/GDP	0.10*	–0.19*	0.22*	0.47*
Anticipated effects – Spain				
Output	1.20*	1.57*	0.94*	0.18*
Net taxes	0.40*	0.59	0.31	0.08
Government purchases	0.83*	0.93*	0.29*	0.07*
Private consumption	0.56*	0.72*	0.24*	0.08*
Long-run interest rate	1.71*	0.31	1.40	2.29*
Budget balance/GDP	0.06*	–0.30*	–0.04*	0.32*

Notes: * denotes statistical significance at the 10% level. The impulse responses are expressed as a percentage of the underlying variable, except for the long-run interest rate, which is in basis points, and the budget balance to GDP ratio, which is expressed as a percentage of the GDP.

Table 8. Responses to a fiscal shock of a 1% decrease in taxes as a share of the GDP under the hypothesis of a large government debt

Budget deficit < 3%	Impact effect	After one year	After three years	After five years
Anticipated effects – France				
Output	0.39*	0.46*	0.22*	0.11*
Net taxes	–0.93*	–0.67	–0.19	0.02
Government purchases	0.65*	0.83*	0.20*	0.05*
Private consumption	0.30*	0.36*	0.07*	0.03*
Long-run interest rate	0.02*	0.02	0.01	0.00*
Budget balance/GDP	–0.45*	–0.58*	–0.31*	–0.20*
Anticipated effects – Germany				
Output	0.47*	0.73*	0.50*	0.17*
Net taxes	–0.97*	–0.89	–0.34	–0.07
Government purchases	0.82*	0.99*	0.41*	0.19*
Private consumption	0.35*	0.40*	0.08*	0.01*
Long-run interest rate	0.03*	0.03	0.02*	0.01
Budget balance/GDP	–0.44*	–0.56*	–0.28*	–0.15*
Anticipated effects – Italy				
Output	0.29*	0.41*	0.25*	0.01*
Net taxes	–0.73*	–0.55	–0.27	0.02
Government purchases	0.55*	0.62*	0.13*	0.02*
Private consumption	0.14*	0.20*	0.03*	0.00
Long-run interest rate	0.01*	0.01	0.00	0.00
Budget balance/GDP	–0.47*	–0.59*	–0.38*	–0.25*
Anticipated effects – Spain				
Output	0.14*	0.53*	0.18*	0.00*
Net taxes	–0.74*	–0.69	–0.30	–0.06
Government purchases	0.41*	0.48*	0.04*	0.01*
Private consumption	0.11*	0.16*	0.01*	0.00
Long-run interest rate	0.01*	0.01	0.00	0.00
Budget balance/GDP	–0.52*	–0.65*	–0.43*	–0.27*

Notes: * denotes statistical significance at the 10% level. The impulse responses are expressed as a percentage of the underlying variable, except for the long-run interest rate, which is in basis points, and the budget balance to GDP ratio, which is expressed as a percentage of the GDP.

Table 9. Responses to a government spending shock at the zero lower bound policy with long-term commitment (Krugman, 1998) under the hypothesis of a large government debt

Budget deficit < 3%	Impact effect	After one year	After three years	After five years
Anticipated effects – France				
Output	3.11*	3.25*	2.40*	1.03*
Net taxes	–0.68*	–0.59	0.03	0.21
Government purchases	1.40*	1.61*	1.14*	0.27*
Private consumption	1.00*	1.34*	0.69*	0.23*
Long-run interest rate	1.12*	0.17	0.80*	1.68*
Budget balance/GDP	–0.81*	–0.73*	–0.59*	–0.41*
Anticipated effects – Germany				
Output	3.12*	3.41*	2.60*	1.07*
Net taxes	0.19*	–0.15	0.18	0.32
Government purchases	1.60*	1.78*	1.33*	0.51*
Private consumption	1.01*	1.22*	0.79*	0.28*
Long-run interest rate	1.02*	0.12	0.83*	1.66*
Budget balance/GDP	–0.48*	–0.51*	–0.35*	–0.17*
Anticipated effects – Italy				
Output	2.70*	3.19*	2.21*	0.58*
Net taxes	–1.47*	–0.92	–0.39	–0.10
Government purchases	1.16*	1.27*	0.72*	0.15*
Private consumption	0.75*	0.89*	0.58*	0.22*
Long-run interest rate	0.97*	0.10	0.48	1.17*
Budget balance/GDP	–1.59*	–1.91*	–1.06*	–0.78*
Anticipated effects – Spain				
Output	2.37*	2.74*	1.51*	0.27*
Net taxes	–1.97*	–1.68	–0.92	–0.63
Government purchases	0.75*	0.98*	0.59*	0.11*
Private consumption	0.60*	0.81*	0.40*	0.12*
Long-run interest rate	0.92*	0.07	0.42	1.01*
Budget balance/GDP	–1.78*	–2.01*	–1.44*	–0.96*

Notes: * denotes statistical significance at the 10% level. The impulse responses are expressed as a percentage of the underlying variable, except for the long-run interest rate, which is in basis points, and the budget balance to GDP ratio, which is expressed as a percentage of the GDP.

Table 10. Fiscal multipliers in distinct interest rate environments

	i > 0 (positive interest rate)	i = 0 (zero lower bound)
	GDP effect	GDP effect
France		
ΔY/ΔGs	1.090	1.843
ΔY/ΔGs with the government debt effect	0.163	0.199
ΔY/Δtc	0.482	0.619
ΔY/Δtc with the government debt effect	0.002	0.013
Germany		
ΔY/ΔGs	1.173	1.829
ΔY/ΔGs with the government debt effect	0.168	0.217
ΔY/Δtc	0.639	0.850
ΔY/Δtc with the government debt effect	0.004	0.018
Italy		
ΔY/ΔGs	1.135	1.973
ΔY/ΔGs with the government debt effect	0.089	0.094
ΔY/Δtc	0.267	0.451
ΔY/Δtc with the government debt effect	0.001	0.007
Spain		
ΔY/ΔGs	1.124	1.986
ΔY/ΔGs with the government debt effect	0.073	0.090
ΔY/Δtc	0.201	0.373
ΔY/Δtc with the government debt effect	0.000	0.001

Notes: This table shows the fiscal multipliers for the big four eurozone economies with respect to the effects of government spending and tax cuts within two interest rate environments: positive interest rates and zero lower bound interest rates. ΔY, ΔGs, and Δtc refer to changes in the output, government spending, and tax cuts. The government debt effect is represented by the restriction that the budget deficit is not allowed to exceed 3% in the first year of the implementation of the fiscal policy. i > 0 implies that the zero lower bound does not bind in the long run, because nominal interest rates respond to fiscal policy shocks and will increase, while i = 0 exists when the zero lower bound is binding and the nominal interest rate does not respond to the fiscal shocks.